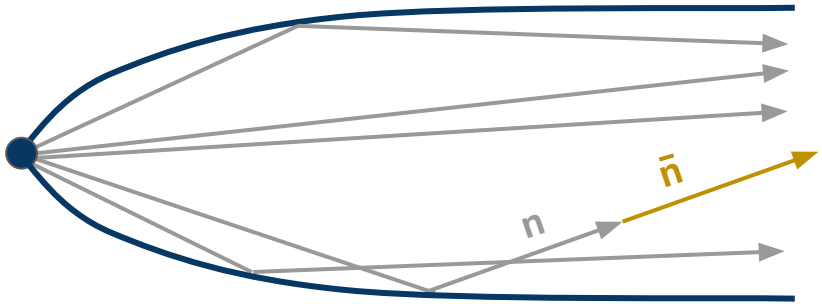


Free Neutron-Antineutron Transformation Searches at the European Spallation Source

K. Dunne
For the NNbar/HIBEAM Collaboration
October 2nd, 2020

Stockholm University
Oskar Klein centre

Snowmass Rare Processes and Precision Frontier Townhall Meeting
RF4: Baryon and Lepton Number Violation Topical Group

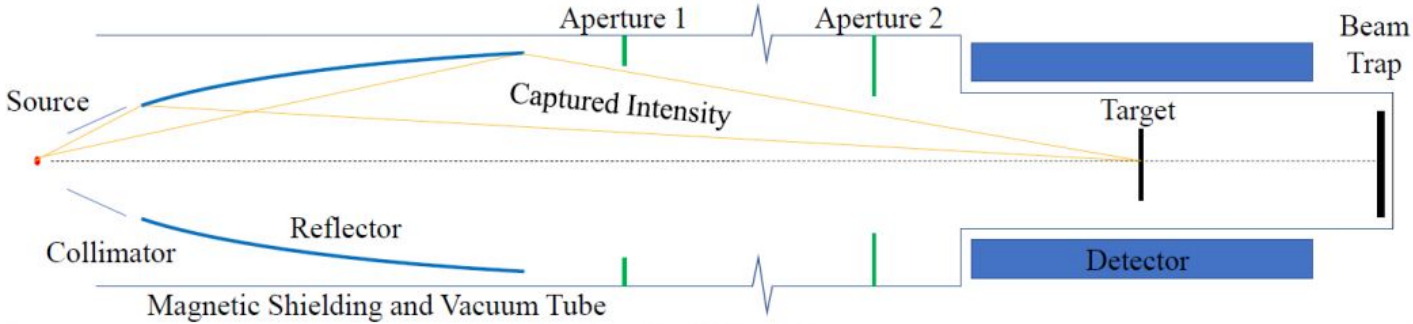
Baryon Number Violation by $\Delta B = 2$

- BNV appears necessary to understand the dynamical development of the matter-antimatter asymmetry
  - Last unobserved Sakharov condition
- BNV is a hallmark of many BSM theories
  - e.g. Post-sphaleron baryogenesis
  - $\Delta B = 2$ probes complementary yet unique physics compared to proton decay and 0ν2β (Super-K, DUNE, etc.)

$n \to \bar{n}$ Searches at Free Neutron Sources

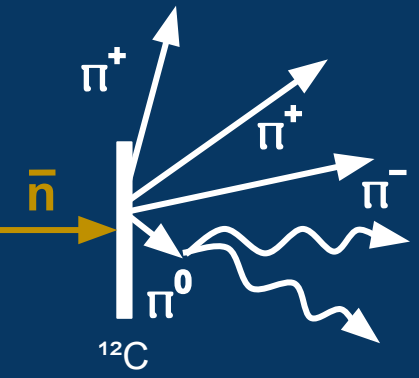
- High precision way of looking for BNV alone
  - Potentially cleaner signal sensitivity compared to intranuclear searches
  - $n \to n'$ ($\Delta B = 1$) dark sector searches offer parallel R&D opportunities
- Unique & underexplored opportunities
  - NNbar/HIBEAM open a new discovery window with free neutron searches

The NNbar/HIBEAM Experiment



- 2 stage experiment HIBEAM(mid2020s) NNBAR(>2030)
- Previous experiment at ILL in 1990s set $\tau_{nn^-} \geq 8.6 \times 10^7$s
- Sensitivity enhanced via 30+ years of advances in
  - Neutronics, optics, moderator design
  - Detector technology
  - Reconstruction techniques
- **Expect ≥10^3 increase over ILL sensitivity:$\langle \phi t^2 \rangle$**
  - Rare opportunity for discovery of testable mechanisms of baryogenesis

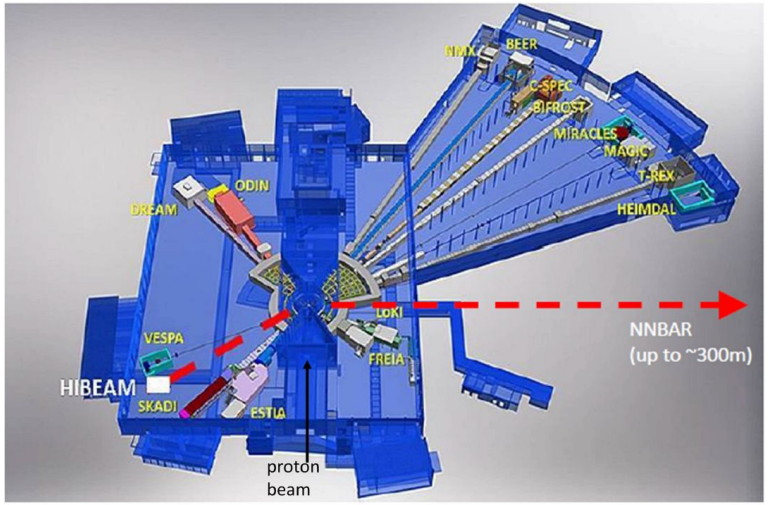
Signal



- Annihilation event in C foil
- More info:
  PhysRevD.101.036008
  PhysRevD.99.035002

The European Spallation Source

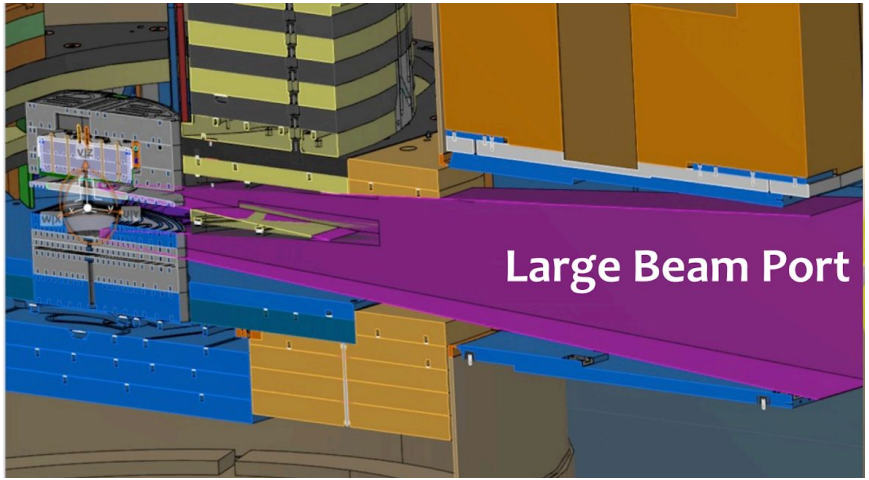
- High intensity, Pulsed cold neutron source
- Under construction in Lund, Sweden
- HIBEAM can run off a fundamental physics beamline expected to be approved soon
- Full NNbar experiment on beamline up to 300m



Factor	Gain v. ILL experiment
Source Intensity	≥2
Neutron Reflector	40
Length ($\propto t^2$)	5
Run Time	3
Total Gain	≥1000

Neutronics

Factor	Gain v. ILL experiment
Source Intensity	≥2
Neutron Reflector	40
Length ($\propto t^2$)	5
Run Time	3
Total Gain	≥1000



Large Beam Port

- Maximized solid angle
- Access 2 moderators
- Constructed for NNbar specifically
- Completely unique from other *n* facilities

Moderator

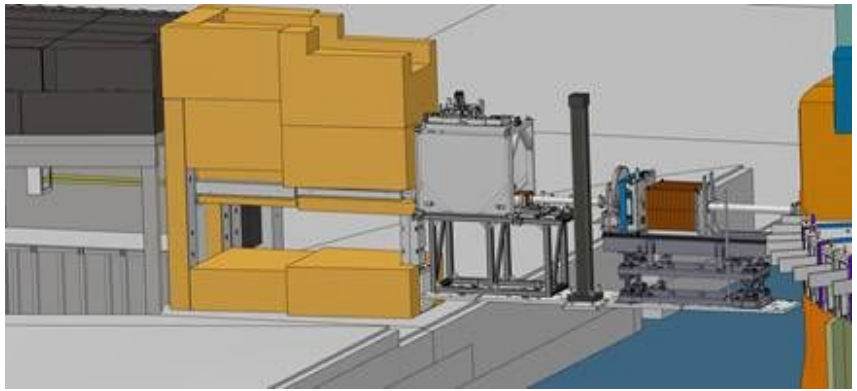
- Upper moderator designed
- Lower moderator design study underway
  - HighNESS (3M€ EU grant)
  - CDR for upgrade of the ESS including NNBAR beamline+experiment.

Reflector

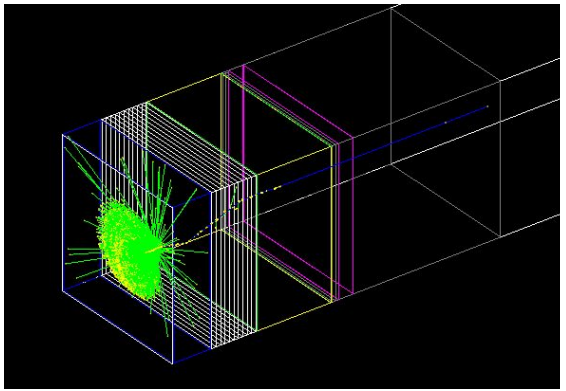
- Large, ellipsoidal focusing supermirror
- Possibilities for novel materials research

R&D Path Towards NNBAR

- Cross-disciplinary effort between nuclear physics, neutronics experts and HEP
- Developments in magnetic shielding, neutron focusing, and moderator design
- Tracking and calorimeter prototypes for in-situ tests
- Beamtime scheduled for nn' experiment before summer at ORNL



ESS Test Beam Line for in-situ background measurements



Tracking and calorimeter simulation in GEANT4

Snowmass

- Contributed Paper will describe our program for neutron conversion studies
- Welcome community input and collaboration, see Letter of Interest

New high-sensitivity searches for neutrons converting into antineutrons and/or sterile neutrons at the European Spallation Source

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- Our Collaboration
  - 26 institutions across 8 countries
  - Co-spokespersons:
    - G. Brooijmans (Columbia)
    - D. Milstead (Stockholm)
  - Technical Coordinator
    - V. Santoro (ESS)
  - Lead Scientist
    - Y. Kamyshkov (UTK)
  - Collaboration with ORNL on neutron conversion program
- See our recent white paper

Stockholm University

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